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Poliomyelitis

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Aware that poliomyelitis is the [Expanded Programme on Immunization] target disease most amenable to global eradication, and that regional eradication goals by or before the year 2000 have already been set in the regions of the Americas, Europe and the Western Pacific, [the Forty-first World Health Assembly] DECLARES *the commitment of* WHO *to the global eradication of poliomyelitis by the year 2000.*

Geneva, 13 May 1988

Poliomyelitis is a viral disease conveyed through fecal-oral and pharyngeal-oral transmission. In unhygienic environments with unvaccinated populations, transmission is widespread, and virtually everyone will be infected (and thereby suffer illness or become immune) prior to age five. Only about 1 percent of those infected experience symptoms, but for that 1 percent the consequences may be death or permanent paralysis. Improving hygiene retards transmission, thereby increasing the average age of disease onset; this leads to epidemics among older children and young adults. As polio paralysis increases in severity with the age of onset, the effect of improved hygiene, in the absence of effective immunization programs, may well be perverse. Highly effective vaccines against polio were developed in the 1950s, however, and the disease is now completely controlled in high-income countries. In low-income countries, polio's inclusion as a target disease in the World Health Organization's (WHO's) Expanded Programme on Immunization (EPI), as well as many strong national efforts, has resulted in progress in reducing disease incidence.

Despite this progress, during the 1980s paralytic polio affected more than 200,000 to 250,000 children per year in the period 1986–88 (Robertson and others 1990). Paralytic poliomyelitis leads to lifelong disability, and the sequelae of past disease has left between 10 million and 20 million youth and adults crippled today. In contrast to its significance as a cause of disability, the contribution of polio to mortality of children under five is relatively modest. Direct evidence from a survey of causes of childhood death in Senegal (Goldberg and McBodji 1988) suggests a contribution to deaths of children under five years old of perhaps 2 per 1,000 live births in an essentially preimmunization environment. This number would constitute about 1 percent of all deaths of those under five years. If applied globally, these figures would suggest that, in the absence of immunization, polio would account for about 150,000 child deaths per year. Lopez (forthcoming) estimates that, in fact, there may currently be about 25,000 deaths per year from polio, although current WHO estimates are somewhat lower at 10,000 (WHO 1990). Polio-related disability in older children and adults is, very plausibly, a risk factor for premature mortality in those age groups, but quantitative assessment of this effect remains to be undertaken. Likewise, we are unaware of studies relating the extent of polio paralysis to earnings or productivity losses, although there is indirect evidence of the importance of these effects. A study from southern India (Max and Shepard 1988) found earning losses of two-thirds and more of annual income associated with moderate degrees of disability resulting from leprosy. This suggests that significant economic benefits (in addition to reduction in suffering) could be derived from prevention. It also suggests that rehabilitation programs could be justified on economic grounds alone if they could reduce a fraction of the earnings disadvantage from paralysis while having costs less than a small multiple of annual earnings.

For polio, the possibility of eradication shapes the discussion of prevention. The quote at the beginning of this chapter from a resolution of the 1988 World Health Assembly states the global goal of eradicating polio by the year 2000. Indeed, polio is one of two diseases—the other is Guinea worm disease—that the International Task Force for Disease Eradication has concluded could be eradicated in this decade. The next section of this chapter deals with several of the most important issues concerning polio eradication; these include questions of feasibility, of the extent to which eradication efforts could divert resources from interventions that would have greater effect on health, and of the extent to which existing immunization schedules could be redesigned to respond more effectively to region-specific conditions. The next main section discusses the generally neglected issue of rehabilitation; although the evidence is sparse, it appears likely that serious attention to and investment in rehabilitation could prove quite cost-effective.

Prevention and Eradication

Immunization is the only primary preventive measure for polio paralysis. Improvement in hygiene, in the absence of immunization programs, can, by raising the average age of disease incidence and hence severity, actually have a deleterious effect, as noted earlier. Sanitation, however, should accompany vaccination. Not only will a more sanitary environment protect children prior to their being immunized, but also, after immunization coverage is relatively high, a sanitary environment will stop or delay transmission and allow more time for an effective response to occasional outbreaks. It is the experience of industrial countries that a moderate vaccination level can interfere with transmission if sanitation is high (Horstmann 1982). Table 6-1 provides a qualitative summarization of how patterns of polio in a population respond to the hygienic environment and vaccination coverage levels.

Immunization

There are currently two highly effective vaccines—the injectable polio vaccine (IPV) and the oral polio vaccine (OPV)—and vaccines with improved characteristics are being developed (Melnick 1988b). Each has been successfully used in high-income countries virtually to eliminate polio, although OPV is much more widely used (Hinman and others 1988). Both vaccines have advantages and limitations for developing countries. When given at the same time, both OPV and IPV are effective, and they do not interfere with each other. In table 6-2 we summarize the characteristics of OPV and compare them with those of IPV. The oral vaccine itself is much cheaper than the injectable vaccine, and it may provide secondary immunization to those in contact with the person who has been vaccinated. The oral vaccine also produces local intestinal immunity, and so it inhibits the transmission of wild polioviruses in a community, although the duration of local immunity is unclear (Beale 1990; Nishio 1984). Additional factors that may favor OPV are that it may be more easily accepted by the population than an injected vaccine (although this is only relevant if polio vaccine is being delivered independently of diphtheria-pertussis-tetanus [DPT] vaccine), and it also simplifies vaccination days or mop-up operations since revaccination is easy and verification of immunization status is not important. The rapid progress to effective control achieved in the Americas is a powerful argument for the effectiveness of OPV in an eradication program. The constraints imposed by use of OPV are the necessity for three or more immunization contacts with the target children, stricter "cold-chain" requirements due to greater heat sensitivity, and an uncertain effectiveness in some tropical settings in which other enteroviruses are present in the environment.

The injectable vaccine protects against poliomyelitis by inducing humoral immunity in vaccinated individuals (Salk 1984). Although it does not induce local immunity, it may reduce the likelihood of polio transmission by preventing pharyngeal excretion of the virus, and, possibly, by reducing virus excretion in stools. The number of IPV injections needed to maintain an enduring immunity has not been established, but two doses appear sufficient to establish initial immunity (Robertson 1988). In European countries such as Sweden and Holland, where IPV alone has been successful in eliminating polio, three injections are given in the primary series, followed by at least two or three booster injections in childhood.

In light of the difficulties of seroconversion using OPV in tropical countries and of interrupting transmission using IPV alone in the same environments, recommendations and testing have been made of a combined IPV-OPV schedule in some developing countries (Melnick 1988b; Tulchinsky 1989), particularly in Asia and Africa. Combined strategies have been successfully used in the West Bank and the Gaza Strip, and they show particular promise in those environments where—for reasons of cost and logistics—many children are still receiving fewer than the recommended numbers of immunizations. Combined strategies would likely rely on OPV for administra-

Table 6-1. Determinants of Patterns of Poliomyelitis

	Level of hygiene	
Vaccination coverage	*Low*	*High*
Low	Polio endemic Infection universal at early age Cases usually less severe than when polio is epidemic 1 percent of all births may result in death or permanent paralysis from polio	Polio endemic Most of population eventually infected Average age of infection may be in teens or young adulthood Cases usually relatively serious
High	Polio may become epidemic unless high OPV coverage is reached Infection levels and average age of onset depend on degree of vaccine coverage May be susceptible population if unvaccinated pockets	Polio controlled Circulation of wild virus interrupted Paralytic polio extremely rare; cases are imported or vaccine associated

Source: Authors.

Table 6-2. Characteristics of Attenuated and Inactivated Poliomyelitis Vaccines

Characteristics	Attenuated OPV	Inactivated IPV
Protects against disease	Yes	Yes
Neutralizing antibodies	Yes	Yes
Vaccine virus		
Excretion	Yes	No
Mutations	Yes	No
Vaccine-induced paralysis	Very rare	None
Mucosal and gut immunity to wild virus	Very high	Very low
Potential for circulation of wild virus in vaccinated population	No	Yes
Number of doses required for initial immunity	Three	Two
Vaccine boosters needed	Yes[a]	Yes[a]
Cost of vaccine dose ($)	0.01–0.05	0.50
Cost of delivery per child contacted for vaccination ($)	1–10	1–10

a. Precise schedules remain to be determined.
Source: Modified and updated from Melnick 1978.

tion at birth when feasible (the so-called OPV-zero) and for occasional mass vaccination days; IPV would be formulated with the DPT shot into a single injection.

Taking all these factors into account, EPI "continues to recommend OPV as the standard EPI antigen for the control of poliomyelitis because of its low cost, dissemination within a community and its record of efficacy" (WHO n.d., p. 11). Nonetheless, it might be more cost-effective to add IPV selectively into the immunization schedule in some geographical areas (Martin 1984). Research is continuing into the effectiveness of schedules combining OPV and IPV compared with those that rely entirely on IPV.

The Cost-Effectiveness of Immunization

The World Bank's Health Sector Priorities Review, of which this chapter is a part, is using two model populations of 1 million to illustrate the magnitude of problems and the cost and effectiveness of interventions. In this subsection we provide estimates of the cost-effectiveness of immunization in these two populations. (The high-mortality population is assumed to have a life expectancy of fifty-one years and an infant mortality rate (IMR) of 129 per 1,000; the low-mortality developing country has a life expectancy of sixty-four years and an IMR of 51 per 1,000.)

Because the timing of administration of polio vaccine corresponds closely to that for DPT, and because the probable administration of IPV should actually be combined with DPT into a four-antigen formulation, the economics of polio vaccination cannot be separated from that of DPT. Underlying this conclusion is the assumption that when polio vaccination costs and effects are considered marginal to those of DPT, the cost-effectiveness of including polio will be very high; calculations strongly support this assumption.[1] Table 6-3 shows illustrative (but plausible) mortality in cohorts of 10,000 births in high- and low-mortality environments, with and without effective vaccination programs. The data in the table suggest that full immunization of the cohort in a high-mortality environment might avert between 170 and 180 deaths in the cohort of 10,000; that is, it might reduce the IMR by 17 or 18 from the the initial level of 129; in the low-mortality environment, the reduction might be about 7 or 8 from 51. These are, of course, highly significant mortality reductions; in addition, assuming an 85 percent effectiveness for polio vaccination, perhaps 50 cases of paralytic polio would be averted (in each environment). After several years of this level of coverage, eradication of local polio could be expected; new cases of disease would drop to zero.

Under conservative assumptions about vaccination program costs (that is, assuming that three contacts per child are required at a cost of $4 each for a total of $12 to immunize against DPT and polio), the cost per child death averted in an immunization effort that covers DPT plus polio is about $670 in a high-mortality environment and about $1,600 in a low-mortality environment. If we assume a 3 percent discount rate, a loss of 0.2 healthy life-years per affected person per year resulting from mild-to-moderate paralysis, and a loss of 0.6 healthy life-years per person per year resulting from severe paralysis, it becomes possible to combine the effects of polio disability averted with the mortality reduction effects of vaccination. The cost per healthy life-year gained is, then, about $20 in the high-mortality environment and about $42 in the low-mortality environment; these costs would go up by about 10 percent and 25 percent, respectively, if polio disability were not considered. Other causes of mortality would, of course, reduce the gains from vaccination; the effect is probably small—perhaps a 10 percent increase in cost per year of healthy life gained in a high-mortality environment and 5 percent in a low-mortality one.

We stress that the numbers in these examples are illustrative and would, most obviously, vary from country to country for many reasons. In particular, as program coverage expands, one expects rising marginal costs, and different countries will be at different levels of current coverage and will be facing different environments. These numbers do give a sense of typical marginal cost-effectiveness in two environments, though, and the

Table 6-3. Effects of DPT and Polio Vaccination on Deaths in High- and Low-Mortality Environments
(per 10,000 births)

Disease	Deaths in high-mortality environment[a]		Deaths in low-mortality environment[a]	
	Without vaccination[b]	With vaccination[c]	Without vaccination[b]	With vaccination[c]
Polio	15	0–1	15	0–1
Diphtheria	12	1	5	0
Pertussis	110	11	55	11
Tetanus[d]	60	3	15	1
Total	197	26–27	90	12–13

a. The high- and low-mortality environments are characterized by infant mortality rates of 129 per 1,000 and 51 per 1,000, respectively.
b. Estimates come from various sources, including EPI program documents, and are approximate.
c. Estimates assume complete coverage with recommended doses of potent vaccine. The assumed efficacies of the vaccines are: polio, 85 percent; diphtheria, 95 percent; pertussis, 80 percent; tetanus, 95 percent.
d. Excludes neonatal tetanus.
Source: Authors.

cost-effectiveness conclusions serve to give a rough sense of the attractiveness of vaccination against these conditions. Findings from other chapters of this collection allow these estimates of the cost-effectiveness of DPT-plus-polio immunization programs to be placed in perspective. Although noticeably less cost-effective than immunization to prevent neonatal tetanus or measles, say, immunization for DPT and polio is solidly among the most cost-effective interventions for children (Jamison, chapter 1, this collection).

Global Eradication

In May 1988 the Forty-first World Health Assembly declared the goal of global eradication of poliomyelitis by the year 2000 (World Health Assembly 1988). An international consensus for the global eradication of poliomyelitis had been building for some time, spurred on by the successful eradication of smallpox in 1977. Similarities in the epidemiologic characteristics of the diseases (spread by human contact) and the availability of effective vaccines suggested that poliomyelitis, like smallpox, was eradicable (Hinman and others 1987). In the 1980s the intensification of immunizations as part of primary health care and the Expanded Programme on Immunizations stimulated marked improvements in polio vaccine coverage, and recent estimates (WHO 1990) suggest that coverage with the third dose of OPV ranges from 47 percent in Africa to 91 percent in the western Pacific region. By 1985 the Pan-American Health Organization (PAHO) and the regional offices of the World Health Organization for Europe and for the western Pacific had declared regional polio elimination targets for the years 1990 and 2000, respectively, and enormous progress has been made toward this goal. In the Americas, there were only 130 cases of paralysis in 1989 that were confirmed as polio-related (*MMWR* 1990); preliminary estimates for 1990 suggest that this number had dropped to 10. Sufficient progress had been made by March of 1988 that the Child Survival Task Force meeting at Talloires in France declared the target of global eradication of polio by the year 2000, preparatory to the World Health Assembly resolution.

What are the implications of an eradication strategy, in comparison with current control strategies? What lessons can be drawn from biologic and epidemiologic similarities (and differences) between polio and smallpox? Is global eradication of polio technically feasible? If so, what are the operational and program design issues associated with the adoption of such a strategy? These questions are addressed in turn.

SPECIFYING ERADICATION STRATEGIES. Stages of control of infectious agents range from effective control to regional elimination to global eradication. In effective control polio immunization EPI is aimed at reducing disease incidence. Regional elimination, the goal in Europe and the Americas, aims at complete cessation of continuous indigenous transmission of wild virus within a specific region. After regional elimination, certain control measures may be dropped and others relaxed; but immunization, plus detection and control of imported cases, must be continued. Global eradication of a disease like polio is the complete and permanent cessation of the natural transmission of the wild virus. After certification of eradication of the disease, vaccinations cannot be stopped permanently until further studies prove the wild virus and virulent strains of the OPV virus are no longer present in the world. It should be emphasized that the World Health Assembly's goal for the year 2000 does not go as far as proven elimination of wild virus; rather, with continued immunization and containment programs, EPI hopes, in the next decade, to reduce to zero the actual incidence of disease. The cost savings associated with being able to cease control efforts, which were an important consequence of smallpox eradication, cannot, however, be expected for polio until, perhaps, substantially after the year 2000.

It is important to recognize that although these programs represent a spectrum of goals, the strategies are fundamentally different in ultimate objective, time frame, and operational translation. Effective control has the modest goal of reduction of the disease burden, and, in the case of polio, the strategy is broad immunization coverage. Regional elimination requires extremely high immunization coverage to levels in which natural transmission is interrupted completely. The strategy is

the maintenance of high vaccine coverage with concurrent surveillance, detection, and control of imported cases. The goal of eradication is to interrupt natural transmission worldwide completely and permanently. The time dimension is critical because there is both the need to attain interruption of transmission as well as the need to achieve complete eradication before political and popular support wane from fatigue or decreasing awareness of the threat of the disease. Even after complete eradication of polio as a disease has been certified, vaccination will have to be continued and the situation evaluated for years before all control measures can be dropped.

IS ERADICATION FEASIBLE? Success with eradication of smallpox raises the question of whether polio has similar characteristics that also make it amenable for potential eradication (Fenner and others 1988). The main similarities between smallpox and polio viruses are the limitation of the virus to human hosts, and that there are no long-term carriers. Several features of poliomyelitis epidemiology suggest that eventual eradication of polio is technically feasible. Effective and cheap vaccines are readily available, and recent experience suggests that complete interruption of natural transmission is feasible (Sabin 1984). In the United States, where nearly 97 percent of school-age children are immunized, naturally acquired indigenous polio has not been reported since 1979. Similar effects of mass vaccine coverage have been observed in Western Europe. Considerable success has also been achieved in certain developing countries, for example, in Chile (no cases since 1975), Cuba (one case since 1973), Costa Rica (no cases), and Brazil (a tenfold reduction of cases since 1980 as a result of mass campaigns during national vaccination days) (PAHO 1985). Indeed, as of April 1989, for the Americas as a whole, "the data appear to indicate that circulation of the wild virus is limited to a few areas of the Andean region (Columbia, Peru, and Venezuela), the Northeastern region of Brazil, and a few areas of Mexico" (PAHO 1989, p. 1). De Quadros and others (1991) provide an overview of recent progress in the Americas and describe the strategies responsible for success.

The biologic differences are numerous, however. These include the existence of three serotypes of poliovirus (rather than one), although the three types have proven to be stable for the past fifty years, so no change in vaccine composition has been necessary. In addition, polio differs markedly in its high ratios of asymptomatic infection.

Not only are there biologic differences between these viruses, but these differences have important implications for the programmatic control of the viral diseases (table 6-4). First, controlling the transmission of poliovirus is far more difficult than controlling the spread of smallpox. The ease of poliovirus transmission and the fact that the overwhelming proportion of infections are asymptomatic render containment much more difficult. Since the fecal-oral route is the primary mode of spread of poliovirus, improved sanitation should help to interrupt transmission.

Second, vaccination around a case of paralytic poliomyelitis would require mop-up operations in whole areas and may not be as effective as vaccination around index smallpox cases. Effectiveness depends, however, on the geographical mobility of the virus, which recent experience suggests is limited. Paralysis is a rare consequence of polio infection; and by the time paralytic cases are recognized, poliovirus may have been widely transmitted. Ultimately, polio eradication may be far more dependent upon mass vaccination than on focused immunization efforts around index cases. Worthy of note is that the mass immunization strategy undertaken in the attempt to eradicate smallpox was extraordinarily difficult and failed in many developing countries.

Third, persons not vaccinated against polio are not as easy to identify as those without smallpox vaccinations. This constraint becomes particularly important for a vaccine which requires multiple doses for effective protection, since partially immunized subjects require identification and revaccination. Consequently, mass vaccination for polio at certain times of the year has been recommended, with OPV being given to all young children. This strategy has been used by PAHO in the Americas and constitutes a definite advantage of OPV over IPV for polio-only vaccination days.

Finally, although the smallpox and the oral and injectable polio vaccines are biologically effective, the polio vaccines are less stable than the smallpox vaccine, especially in tropical climates; they require multiple doses to achieve protective antibody levels; and the cost-effectiveness of a containment strategy of immunizing around index paralysis cases remains uncertain, although recent experiences in the Americas are very encouraging.

Table 6-4. Criteria and Methods of Assessment for Smallpox and Poliomyelitis

Assessment criterion	*Assessment method*	
	Smallpox	*Poliomyelitis*
Virus in environment	No environmental tests required; only human-to-human spread	Test sewage or fecal samples for virus carriage
Immunity in population	Scar good indicator	Serosurveys
Subclinical infections	None; unusual	Viral isolation or serologic tests
Clinical disease	Characteristic rash; sometimes confused with chickenpox	Persistent flaccid paralysis; other viruses can cause paralysis, but rarely this type
Prevalence of clinical disease in area	Presence of clinical cases	Lameness survey

Source: Modified from Evans 1984.

For all these reasons, then, eradication of poliomyelitis will prove more difficult than was eradication of smallpox. Nevertheless, the efforts to eradicate polio benefit from (and contribute to) a massive global immunization program that was totally lacking when smallpox eradication commenced. And in all, vaccination trends plus current and past experiences in polio control suggest that if success is not attained by the year 2000, it should come soon thereafter.

IMPLEMENTATION AND PROGRAM DESIGN. The 1988 World Health Assembly resolution that declared the commitment of WHO and its member states to global eradication of polio recommended a three-pronged attack: (a) achievement and maintenance of high immunization levels, (b) effective surveillance to detect all new cases, and (c) rapid and vigorous response to the occurrence of cases. Countries which have over 70 percent vaccine coverage are encouraged to focus on the elimination of natural transmission, whereas countries with lower vaccine coverage are encouraged to accelerate immunization delivery. Wherever natural transmission has ceased, it should be so confirmed. The director-general of WHO was requested to strengthen planning, training, and supervision within national programs; to enhance monitoring and evaluation; and to improve disease surveillance, clinical laboratory, and vaccine production and quality services. Close cooperation with UNICEF (United Nations Children's Fund) and the Rotary International (*Polio-Plus*) was recommended, and a major resource mobilization effort to seek "extrabudgetary contributions" was mandated.

In pursuing this strategy, certain impediments to eradication were identified. These are political and social will; management constraints; vaccine effectiveness, stability, and cost; and adequacy of surveillance.

The lessons learned from smallpox eradication suggest certain areas that deserve attention. First, the polio eradication effort will be an integral part of EPI and not an entirely separate effort. The smallpox program, in contrast, was greatly facilitated by its organization as a special program with specific targets and a limited time frame. To fulfill its goals, it had a full-time technical staff, at one stage numbering more than 100, and earmarked resources and internally established working procedures. The WHO resolution specifically emphasizes the importance of strengthening EPI and primary health care through polio eradication activities, and the key role of increasing vaccination coverage (including all EPI antigens) is stressed in recent program descriptions. Given the polio eradication effort as currently articulated, there should be no competition between polio eradication and other EPI or primary health care objectives.

Second, plans for polio eradication implicitly call for an articulated strategy that emphasizes both general health service objectives (higher general vaccine coverage) as well as special vertical efforts (surveillance, special immunization efforts around index cases, and national polio vaccination days). Experience from industrial countries has demonstrated that high levels of general coverage are feasible, assuming strong health infrastructure, and can lead to the interruption of natural transmission. In many developing countries, however, the maintenance of high levels of general vaccine coverage may be operationally difficult or unsustainable at present. Understandably, vertical efforts such as national vaccine days have encountered some success. The implication of larger-scale, vertical efforts such as these on the existing health care system will vary considerably between countries. The experience of PAHO in the Americas is very illustrative. Polio vaccination has been used as the leading edge for EPI, and the use of all vaccines has been encouraged on immunization days.

Third, the smallpox program had built-in applied research with sufficient programmatic flexibility to adapt management of program structures to specific country situations. Indeed, the smallpox experience demonstrated that research and learning led to many programmatic modifications. Such research and adaptive managerial responses are being developed and successfully used in the Americas, where the global effort has recently articulated a research program.

Case Management

The true dimensions of the tragedy of poliomyelitis worldwide can be understood, not from the incidence figures given earlier in this chapter, but only by the realization that poliomyelitis will lead each one of the paralyzed individuals to a lifetime of disability. A child that suffers polio in 1990 and who lives sixty years will still be a member of the disabled population in the year 2050. Even if polio were eradicated by the year 2000, there would still remain well into the next century 10 million to 20 million persons paralyzed from poliomyelitis. The aims of rehabilitation are to facilitate integration of these people into the family and community of polio victims, transforming their personal and social expectations and contribution. In most developing countries, few individuals suffering disability from poliomyelitis receive treatment. This situation is not unique to polio. Probably no more than 1 or 2 percent of all disabilities in developing countries are actually treated (Shirley 1983).

There is a complex set of political, structural, and cultural reasons for this situation (Heim 1979; Vossberg 1985). First, rehabilitation and treatment of disabled individuals have been a low priority for governments because of a lack of recognition of the extent of the problem and an underestimation of the burden it poses. Incidence figures of poliomyelitis, when compared with those of acute diseases, underrepresent the true burden of the disease, which amounts to a life of disability, suffering, and lost productivity. Besides an underestimation of the true burden of the disease, another reason why governments have given low priority to rehabilitation programs is that disabled individuals are a marginal population and have little ability to influence policy. Second, there is a problem of access. Existing rehabilitation services tend to be located in urban areas and to be costly. Finally, there are cultural reasons: disabled individuals may be rejected by their communities, denied, or hidden. And in general there may be a fatalistic attitude that nothing can be done to improve the living conditions of persons with paralytic disabilities.

Despite this current inattention to rehabilitation, there is a wide range of interventions that can reduce the level of disability and improve the quality of life of persons suffering from paralytic polio (Ajao 1981; Huckstep 1970; Werner 1987; WHO 1982). Many of the needed interventions, with the exception of surgery, can be easily learned and practiced by family members of disabled individuals or by other disabled individuals themselves who are trained as rehabilitation, primary care, or other types of health workers. This is true for other motor disabilities as well, which suggests the value of an integrated approach to rehabilitation.

Rehabilitation of polio paralysis in the first few days after the onset of paralysis is oriented to reducing the pain associated with muscle spasm. Hot wet packs, warm baths, dry heat, changing the position of paralyzed limbs and moving the patient in the bed are all effective in reducing frequency and intensity of pain. In the weeks following the attack, and once pain has disappeared, physiotherapy can be initiated on a daily basis. The aims of physiotherapy are (a) to strengthen muscles, and (b) to limit deformities and contractures by putting limbs through a full range of passive movements. Physiotherapy needs to be continued for several months in order to be most effective (Coovadia 1984).

Once paralysis is established, usually one to two years after disease onset, rehabilitation, through physiotherapy, is oriented to overcome deformities resulting from rigidities and contractures. Severe or old deformities will often need surgery to be corrected, which suggests the secondary preventive value of early intervention. Once limbs are returned to their most functional positions, appliances are needed to correct residual lesions, like leg length inequalities, or to facilitate motion (Coovadia and Loening 1984).

Prostheses and aids can be cheaply and appropriately produced in developing countries, frequently with material available in the same communities where they are to be used (Barneji 1984; Eyre-Brook 1986; Sankaran 1984). Importation of orthopedic devices is costly and often inappropriate because of cultural differences and difficulties of maintenance (Abayoni 1981).

Rehabilitation programs in developing countries face many challenges. The most important ones are lack of trained professionals and a large, dispersed rural population with limited access to rural rehabilitation services. A number of programs in developing countries are successfully providing rehabilitation services to underserved populations. One of them is the Projimo project in Mexico (Werner 1987). This project is run by disabled individuals of the locality, whose education averages three years. In the experience of this project only 10 percent of the disabled individuals in the area needed specialized services that had to be provided outside at a referral center. The operating cost of this program is about $9 per patient per year.

This experience of those in this and other projects (Barneji 1984; Eyre-Brook 1986; Sankaran, 1984), points out that tertiary and secondary facilities can be effectively linked to community-based projects. Such linkage can widen the coverage that specialized programs offer and increase their effectiveness. The typical cost of operating a community-based project remains to be worked out. Although the cost of attending an individual patient will likely be low, the cost of effective supervision and training may well be important. Table 6-5 summarizes the nature of case management interventions that might be delivered at various levels of referral, including the household level.

Current experiences in developing countries provide some insight and guidance (often untapped) on ways to approach these problems. The main lesson is that viable options exist for the disabled, even in very poor countries. In this context, it is encouraging that WHO feels that "[p]olio eradication will provide a setting in which significant improvements in rehabilitation services can be undertaken" (WHO/EPI 1989). It is important that these sentiments be backed by resources.

Conclusions

Poliomyelitis has, historically, imposed a significant (but most often underrecognized) burden on the world's population. Prior to the development and introduction of vaccines, more than five out of every thousand children born would have been seriously affected by the disease, most typically with permanent lameness. Programs built around the highly effective and relatively low-cost vaccines now available have greatly reduced the global burden of poliomyelitis. Available technologies hold the promise of being able to eradicate poliomyelitis, and

Table 6-5. Management of Cases of Paralytic Poliomyelitis

	Level of intervention			
Objective	*Household*	*Primary facility*	*District hospital*	*Tertiary hospital*
Rehabilitation	Passive movements	Passive movements; functional postures	Physiotherapy; corrective surgery	Corrective surgery
Secondary prevention	Posture playing; passive movements	Appliances; passive movements; social integration	Physiotherapy; corrective surgery	Corrective surgery
Palliation	Pain reduction with hot wet packs and warm baths	Painkillers and pain reduction with hot wet packs and warm baths	Painkillers and pain reduction with hot wet packs and warm baths	Painkillers and pain reduction with hot wet packs and warm baths

Note: Cure is not an objective at any level of intervention.
Source: Authors.

the World Health Organization is providing global leadership to achieve this goal by the year 2000. Yet moving toward eradication raises difficult economic and managerial issues, particularly for the poorest countries; and the question of how to provide minimally adequate rehabilitation for the hundreds of thousands of new cases every year, and the 10 million to 20 million existing cases, remains to be addressed.

Our main conclusions deal with these issues:

- The commitment to polio eradication by the year 2000, within the context of EPI, deserves strong national and international financial and technical support. With such support, sustained throughout the 1990s, it is reasonable to hope that polio will be eradicated by the year 2000 or soon thereafter. It will probably prove unwise to advance eradication through substantial expenditure on polio-only activities; although such a less-focused, broader approach may delay eradication somewhat, it will maximize the cross-benefits of political concern for polio by increasing the efforts put forth generally to strengthen EPI and primary health care.
- There are now available, in OPV and IPV, two highly effective vaccines; the choice of OPV or IPV or a schedule that relies on both should consider the epidemiological, economic, and logistic realities of each country. At present, schedules based on OPV are recommended by WHO as globally most desirable; a careful assessment, by country or by region, of the effectiveness of alternative vaccination schedules, given their costs, might suggest the desirability of different schedules for different environments.
- Effective interventions exist both to reduce disability from paralytic polio and to (partially) rehabilitate the already disabled. Little, concretely, is known about the costs, short-term effectiveness, or long-term benefits of programs based on these interventions. Yet the available evidence strongly suggests that much more should be done and could be done at modest cost; there is no justification for continued neglect of rehabilitation.

Appendix 6A. Epidemiology of Polio

In this appendix we first discuss the general characteristics of polio and then turn to several specific aspects of descriptive gender differences in epidemiology, results form lameness surveys, and incidence trends.

General Characteristics

Poliovirus belongs in the family Picornaviridae, genus *Enterovirus*. They are small icosahedron-shaped viruses with a protein coat and an RNA core and do not contain lipids. There are three main antigenic types, with many intratypic differences, and they are identified by type, place, strain number, and year of isolation. Poliovirus 1 predominates in unvaccinated communities, and types 2 and 3 are responsible for most outbreaks in vaccinated populations (Assaad and Ljungars-Esteves 1984).

The poliovirus enters the body through oral ingestion and initially multiplies in the lymphoid tissue. The incubation period is usually seven to fourteen days, but it may range from three to thirty-five. Through dissemination in the blood stream, the virus may invade anterior horn cells (motor neurons) of the spinal cord, and in the process of intracellular replication, poliovirus may cause temporary or permanent loss of neurologic function due to inflammation. Following the attack, most individuals will recover completely. In rare cases, permanent damage or complete destruction of the nerve cell leads to irreversible paralysis. The infection stimulates permanent local and serum immunity to the viral type causing the infection (Paul, Riordan, and Melnick 1951). Local immunity prevents reinfection in the gastrointestinal tract (Melnick 1982).

Only about 1 percent of the total infections will produce clinical symptoms. The most common form of poliovirus infection is asymptomatic. Severe illness may follow nonspecific symptoms of infection—fever, malaise, sore throat, and symptoms of aseptic meningitis—but most often, severe disease is preceded by no manifestations of disease. Characteristic signs of severe disease are a flaccid paralysis—due to lower motor neuron damage—typically asymmetric for limbs and with no loss of sensation. In table 6A-1 we show a hypothetical pattern of outcomes for 10,000 cases of infection with poliovirus.

Besides the immediate paralysis, affected persons suffer in subsequent years or decades an aggravation of paralysis and intense symptoms of asthenia, fatigue, or pain. These late effects of poliomyelitis typically manifest themselves several decades after the onset of primal paralysis, sometimes leading to a severe incapacitation of individuals who were previously only moderately affected. Two factors may play a predisposing role to late effects of poliomyelitis: older ages at polio onset and an initially severe presentation of the disease (Halstead 1985).

Polioviruses can maintain their infectivity in water, unpasteurized milk, and other food products (Robbins and Nightingale 1986). Polioviruses replicate, however, only in human beings, and man is the only known reservoir. The viruses multiply in the alimentary track—throat and lower intestine—and are eliminated with feces. The virus can then be found in the stools of infected persons for a period of one or two months. Contaminated water may be an important route

Table 6A-1. Typical Outcomes among 10,000 Cases of Poliomyelitis

Outcome	*Number*
Asymptomatic	9,900
Symptomatic	100
Death	15
Complete recovery	25
Mild paralysis	30
Moderate paralysis	15
Severe Paralysis	15

Source: Authors' estimation from epidemiologic findings; Basu and Soc Khey 1984.

of transmission in most developing countries (Evans 1984), and although polioviruses are resistant to the action of lipid solvents, they can be rendered inactive by chlorination of water. Standard sewage treatment does not usually eliminate poliovirus from the effluent (Melnick 1982). Besides stools, droplets from coughing or sneezing can also be a source of transmission in the early stages of the infection. Increased risk of paralysis has been reported following intramuscular inoculations (Guyer 1980; Wyatt 1985).

Hygiene, sanitation, and poverty are primary determinants of the environmental prevalence of the viruses and consequently of the average age at first infection (Horstmann 1982). In unvaccinated populations of developing countries almost all children are exposed to polioviruses before five years of age. Given the low mortality rate from infection (indicated in table 6A-1), the contribution of polio to mortality of children under the age of five years would be very modest—only 1.5 per 1,000, out of the approximately 90 per 1,000 in Asia, or the 170 per 1,000 in Sub-Saharan Africa. That figure was found to be about 2 per 1,000 in a preimmunization environment in West Africa (Goldberg and McBodji 1988).

The pattern of polio transmission in now-industrial countries before the advent of mass vaccination provides excellent evidence of changes in epidemiologic patterns related to environmental conditions, mainly hygiene and sanitation. In the epidemic of 1916 in the United States, 80 percent of the cases were in children below five years of age. A few decades later, before vaccination was started, the average age had moved higher, to five to nine years, with one-third of the cases above fifteen years. In both the 1916 and 1950 epidemics, children from higher socioeconomic classes, who, presumably, were less exposed at young ages, experienced a higher mean age of disease and, consequently, more severe cases. Historically, in industrial countries, before mass vaccination, children of higher economic groups were infected at older ages than those of lower socioeconomic ones. Those stricken at older ages are more likely to develop more severe forms of disease.

Traditionally, in tropical countries poliomyelitis has been an infection of infants. In those countries, the virus has been widely distributed in the environment, and passive immunity conferred by the mothers to the newborns may have provided some early protection in infants that reduced the presentation of severe forms of disease. Among the nonimmunized, infection would have invariably occurred early in life (Melnick 1988a and 1988b). As sanitation and general development improves, a shift from endemic to epidemic patterns of polio transmission is observed. The overall incidence of severe paralytic disease appears to increase along with older mean age of infection and the transition from endemic to epidemic disease transmission (Fang-Chou and others 1982; Goldblum and others 1984).

The experience of industrial countries is that the incidence of disease drops soon after mass immunization is introduced (Kim-Farley, Rutherford, Lichfield, and others 1984). Except for some imported strains, wild polioviruses for the most part either have been eradicated or are in the process of being eradicated from most industrial countries. The experience of some countries, such as the Netherlands, the United States, Spain, China, and Taiwan, demonstrates that, even with high vaccination coverage, there are opportunities for occasional epidemics in unvaccinated segments of the population; for discussion of a relevant outbreak in Taiwan, see Kim-Farley (1984b). Those experiences underscore the need for good surveillance and rapid interventions as essential features of control and eradication strategies.

Gender Differences

Table 6A-2 is a summary of reported gender differences in the prevalence of paralytic poliomyelitis. The figures suggest that

Table 6A-2. Studies Indicating Prevalence of Paralytic Poliomyelitis by Gender

Country (year)	*Number of cases*	*Male-female prevalence*	*Description of study*	*Source*
Senegal (1986–87)	89	1.7:1	Postoutbreak study to assess effectiveness of new IPV; 85 cases were in children under age five; 63 percent were male	MMWR 1988
Senegal (1986)	60	1.2:1	Preliminary phase of above study	MMWR 1987
The Gambia (1986)	305	1.3:1	Investigation of outbreak to assess effectiveness of OPV	Global Advisory Group 1987
Yemen, Rep. of (1980–81)	40	2.5:1	School and community survey of lameness in children aged five to thirteen	Hajar 1983
Jordan (1978–80)	90	2.7:1	Hospital admissions following poliomyelitis outbreak	Khuri-Bulos and others 1984
Germany (1964–82)	27	1.7:1	Reports of paralytic poliomyelitis in recipients of OPV (21) or in contacts (6)	Maass and Quast 1987
United States (1969–81)	203	1.2:1[a]	Cases reported to Centers for Disease Control (CDC)	Moore and others 1983
India (1984)[b]	82	1.5:1	Community lameness survey in Bombay slums in children younger than six years	Tidke, Joshi, and Patel 1986
India (1978)	416	1.5:1	Hospital admissions of children following outbreak	Saeed and others 1980
India (1976–80)	2,953	1.7:1	Assessment of paralytic poliomyelitis victims, including vaccination history and prognosis	Srivastava and others 1983

a. 2.7:1 in vaccinees.
b. Date uncertain.
Source: See table (last column).

Table 6A-3. Prevalence of Poliomyelitis in Population-Based Lameness Surveys

Country	Year	Ages (years)	Children surveyed	Population[a]	Prevalence
Asia					
Indonesia	1977	0–20	57,000	Mixed	0.9
	1978	0–14	10,000	Rural	3
Bangladesh	1979	5–14	25,000	Rural	1
	1983	5–9	35,000	Mixed	2–3
Philippines	1980	0–14	12,000	Mixed	3
India	1981	5–9	358,000	Rural	6 (2–9)[b]
	1981	5–9	357,000	Urban	7 (2–9)[b]
	1985	5–15	6,000	Urban	17
	1986	0–4	27,000	Rural	5
	1987	0–5	10,000	Rural	3
Nepal	1982	5–9	6,000	Rural	2
	1982	5–9	5,000	Mixed	1
	1983	5–9	2,000	Mixed	3
Sri Lanka	1982	5–9	7,000	Rural	0.9
Viet Nam	1983	5–15	5,000	Mixed	1
	1985	5–15	43,000	Mixed	0.6
	1985	0–15	68,000	Mixed	0.5
	1987	0–14	340,000	Rural	0.4
Lao PDR	1985	5–14	27,000	Rural	3
Sub-Saharan Africa					
Ghana	1974	6–15	7,000	Rural	8
Cameroon	1978	5–11	4,000	Mixed	5
	1978	5–11	8,000	Rural	8.5
	1978	5–11	5,000	Urban	8
Côte d'Ivoire	1979	5–14	6,000	Rural	8
	1980	8–12	6,000	Mixed	12
	1980	6–15	5,000	Urban	7
Kenya	1979	5–14	7,000	Rural	0.7
Malawi	1979	0–15	35,000	Mixed	6.5
Swaziland	1979	0–10	6,000	Rural	3
Niger	1981	5–19	14,000	Rural	7
	1981	10–14	10,000	Rural	6
Sudan	1982	5–9	18,000	Mixed	5
Somalia	1982	5–13	51,000	Mixed	10 (6–20)[b]
Ethiopia	1983	5–9	18,000	Mixed	7
Tanzania	1984	0–4	4,000	Rural	0
	1984	5–9	4,000	Rural	2
	1984	10–14	3,000	Rural	5
Middle East and North Africa					
Egypt	1976	0–10	525,000	Urban	2
Morocco	1980	0–4	7,000	Urban	2
	1980	5–9	8,000	Urban	3
	1980	10–14	8,000	Urban	5
Yemen, Rep. of	1981	5–13	6,000	Rural	3
	1981	5–13	6,000	Urban	4
Jordan	1983	0–10	28,000	Mixed	1 (0.4–2)[b]
Pakistan	1984	0–5	10,000	Mixed	8
Iran, Islamic Rep. of	1986	0–15	15,000	Rural	4
	1986	0–15	15,000	Urban	3.8 (2–6)

a. Mixed population is both rural and urban.
b. Prevalence ranges.
Source: Adcock 1982; Bernier 1983; Bernier 1984; Basu 1986; WHO/EPI 1988; Heymann and others 1983; Nicholas and others 1977; Snyder and others 1981; Thuriaux 1982; Ulfah and others 1981.

Table 6A-4. Regional Variation in Vaccination Coverages, Cases of Poliomyelitis, and Mortality, 1985

Parameter	Global	Industrialized market economies	Industrialized transition economies	Latin America	Middle East and North Africa	Africa	Asia
Vaccination coverage[a] (percent)	50	90	85	85	20	50	60
Incidence (per thousand school-age children)	10	0	0	0.25	43	23	11
New cases (thousands)	500	0.1	0.3	0.8	183	81	283
Deaths (thousands)							
Age 0–1 year	24	0	0	0	9	4	11
Age 1–4 years	53	—	—	—	17	7	29
Age 5–14 years	4	—	—	—	1	1	2
Age 15–44 years	—	—	—	—	—	—	—
Age 45–64 years	—	—	—	—	—	—	—
Age 65 years and older	—	—	—	—	—	—	—
Total	81	—	—	—	27	12	42
Percentage of all deaths	0.16	—	—	—	0.37	0.25	0.1
Death rate (per ten thousand)	1.7	—	—	—	5.9	3.1	1

a. For children age five years and younger.
— Not available.
Source: Basu and Soc Khey 1984; Bernier 1984; Fang-Chou and others, 1982; Foster 1984; Hajar and others 1983; Heymann and others 1983; John 1984; LaForce and others 1980; MMWR 1987; PAHO 1985; Ramia and others 1987; Ulfah and others 1981; WHO/EPI 1987.

paralytic poliomyelitis tends to occur more frequently in males than in females. The reported effect varies from a ratio of 1.5 to 1 of males to females, to a ratio of 2.5 to 1, the latter being found in the Republic of Yemen and Jordan. There is no clear explanation for these reported differences, although there are several possibilities. First, since not all prevalence studies report ratios of paralysis between males and females, isolated findings could be attributed to chance alone. Although that is theoretically possible, it is unlikely. It must also be noticed that there are no similar reports showing higher rates of disease in females than in males. Second, the figures could be attributed to biased population reporting of polio paralysis. That could explain some of the extreme ratios reported, but Germany and the United States, both of which have good reporting and recording systems, still show a higher prevalence of polio paralysis in males than in females. Third, some unknown factors may lead to (a) higher fatality rates in girls or (b) to a greater severity of the disease in boys. The male-to-female ratio in prevalence of polio paralysis suggested by the literature—excluding extreme values—would be about 1.4, between 1.2 and 1.7 to 1.

Prevalence of Lameness by Region

Paralytic poliomyelitis leads to significant life-long disability and handicap in affected persons. Surveys have been done all over the world to estimate the prevalence of lameness due to poliomyelitis in developing countries. Important differences have been found not just from one country to another, but within the same country between rural and urban areas. The prevalence of paralytic poliomyelitis in developing countries is, on average, higher than the 3 cases per 1,000 population reported for the United States in 1936. On average, the reported prevalence of disability is about 5 cases per 1,000 school-age children in developing countries, ranging from 0.5 to 19 (Bernier 1984). Most lameness surveys, however, have been based on school-age children, which holds the potential of underestimation of the true burden of the disease. For this report, we have considered population-based surveys and surveys that included the school catchment area. Table 6A-3 shows the prevalence of poliomyelitis detected by lameness surveys in Sub-Saharan Africa, Asia, and the Middle East and North Africa region. If several surveys were carried out simultaneously, prevalence figures reflect average reported figures; if the reported prevalences differ by more than 20 percent, however, the range of reported prevalences is given.

Declining Trends in Polio Incidence

The actual incidence or prevalence of poliomyelitis in the world is not known, but indirect estimates of incidence derived from lameness surveys have suggested a much heavier disease burden than reported cases would suggest. The World Health Organization estimated that almost 250,000 new cases of poliomyelitis paralysis occurred each year from 1984 to 1988. It is unlikely that actual figures will currently be higher than that. On the contrary, there are strong indications that the number of new cases of polio paralysis has declined significantly in the last decade. Table 6A-4 shows our estimation of new cases that would have occurred about 1985 if disease incidence had been the same as estimated from lameness surveys. More than half a million cases of permanent polio paralyses would have occurred if disease incidence had remained unchanged and similar to that of one or two decades earlier. That figure doubles the estimated number of cases for that year and is comparable to the one estimated by WHO for the late 1970s or early 1980s.

Notes

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1. The calculations are reported in the unpublished versions of this chapter.

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